Information Dynamics

A Fresh Look at Information
Its Properties and Implications

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What Information does this picture carry ?

Has it changed recently?

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STORM TEAM 8 Severe Weather
Watches & Warnings
WINTER STORM WARNING
BLIZZARD WARNING

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WHAT INFORMATION DOES THIS SEQUENCE CARRY ?

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What is the basic nature of Information?

Only Sentient entities handle it!

What is Information ?

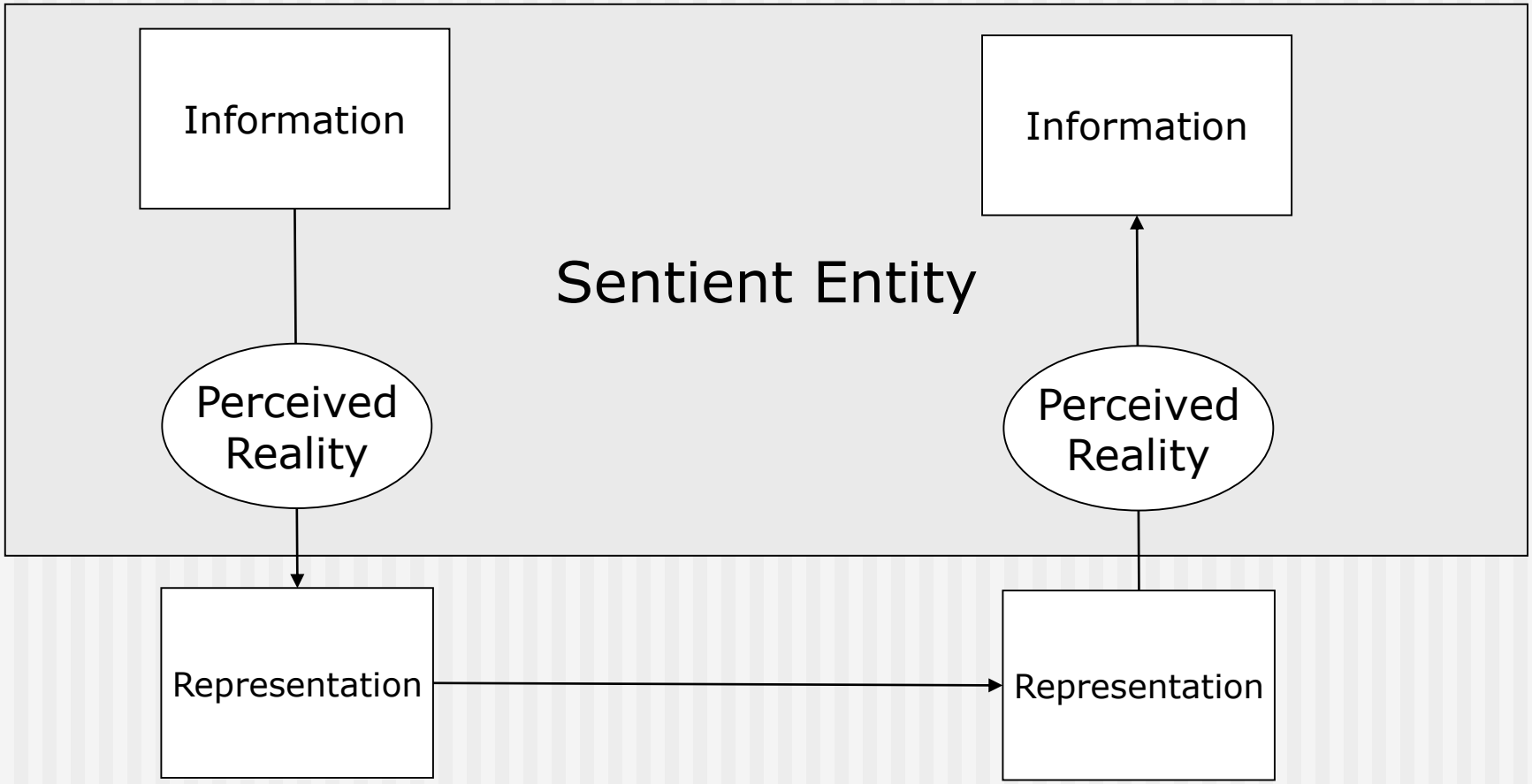
- Information is different from its representation !!

- Can have many representations
  - Are they equivalent??

Information

- Many forms
  - Technical – Shannon
  - Everyday use
- Distinction between information and its Representation

Information and Representation



Information versus its Representation

- No one-to-one mapping
- Representation is meaningless without a relation to the appropriate contextual information
- Must understand the relationship of the representation to the appropriate information
- Representations are transmitted across boundaries via physical means (messaging, voices, etc.)
- All typical manipulations of information are through manipulations of its representation

- How is the mapping carried out?

Perceived Reality

- All a sentient entity knows…
  - Facts
  - Figures
  - Relationships
  - Models
  - …
- …about
  - The environment
  - another entity or system
  - Itself

Perceived Reality

- Any local node maintains its view of the universe and other entities in the form of *Perceived Reality*
- Perceived reality is based on
  - Prior Model of the Universe and Other Entities
  - Explicit information received and processed
    - Explicit information is processed to integrate it with the perceived reality
    - This integration is based on the model of the universe
    - Information may change the model
- All actions are initiated using the knowledge of the perceived reality
- *All systems have been bootstrapped with information to start its "life"*

Models

- Abstraction of an entity or a system.
- Contains properties and relationships believed to be true.
- One part of an entity's perceived reality is the model of another entity.
- Constantly refined by information:
  - New, Refuting, Removing, …

Perceived Reality

- When a message is received
  - Its contents are converted into information based on the current perceived reality
  - That information is assimilated into the current perceived reality
  - A message (representation) can not be converted into information unless the perceived reality contains the means for reverse mapping
    - Language – Symbols - …

What is Information ?

- *Information Entity*

- Information has many
  - interrelationships
    - attributes
    - properties
- Interrelationships are information also
- Such interrelationships exist whether they are enumerated/identified or not

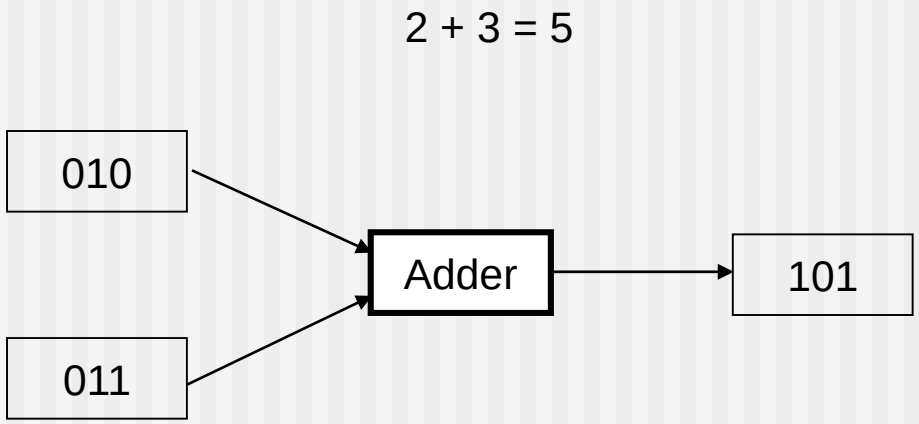
Information and Representation

- From Information to Representation:
  - Some facts will not be retained!
  - Loss of relationships!
- Manipulation:
  - Informational
  - Representational

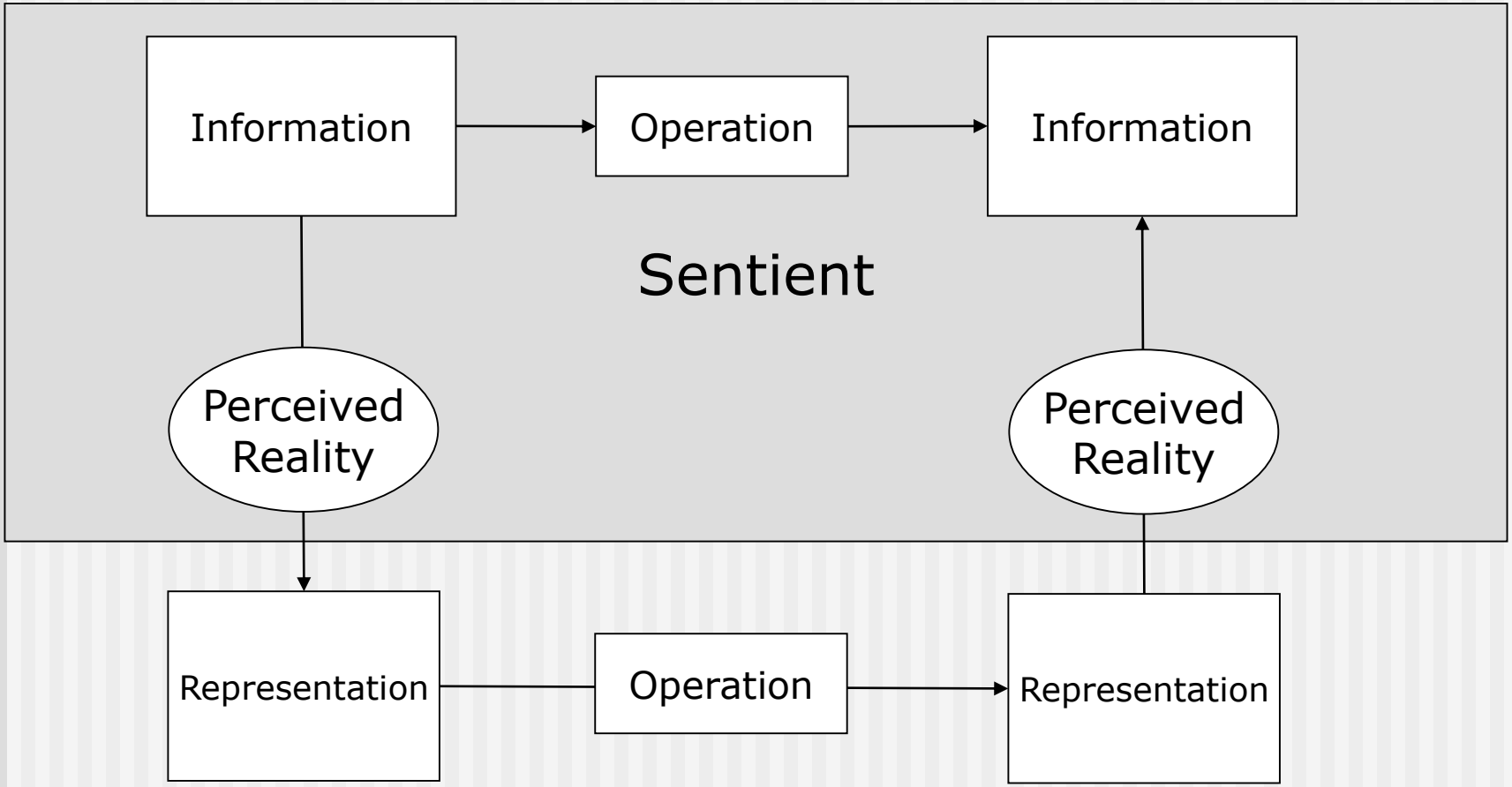
What is Information ?

- Information is handled by Sentient Entities
- Its representations can be handled by machines

- Machines only manipulate representations of information.



Information and Representation



What Is Information ?

- It is a property /description/characteristics of something
- That something may be another piece of information
  - An object – Physical, logical, virtual,conceptual – group
  - An action
  - A trigger
  - A relationship
- Significance of Information is its interrelationships
  - May be direct or indirect
  - Exist whether enumerated or not
  - May be static or dynamic

Typically retain only small amount of information considered relevant in any system

Nature of Information

- Quantifiable
  - Only in the context
    - Temperature in this room
      - Scale
      - Accuracy
      - Time it was recorded
      - Who took it
      - What instrument was used - precision
- Non-quantifiable
  - Most of the information we deal with is of this type

Information Representation

- Representations are essential to store, move, or process information
- Capture only some aspects/views/projections of information –
  - A good system designer carries other aspects in her head.
- Example: Data Structure
  - Contains not only representation of some quantities but also of some relationships

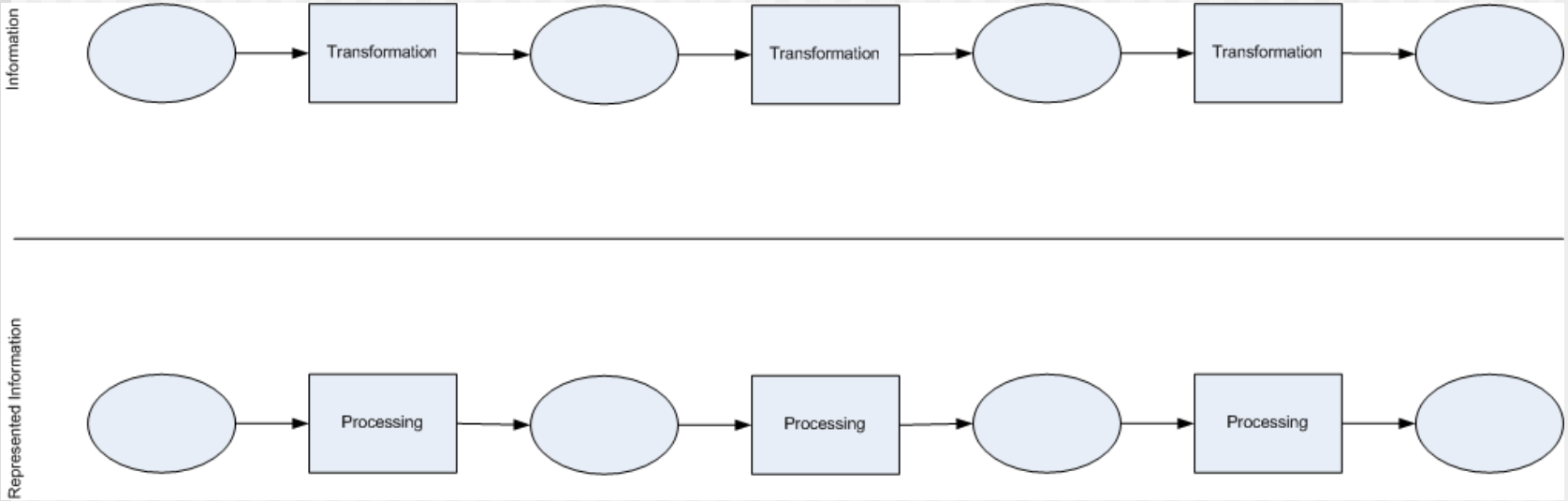
Information Representation

- Use – Requires associating meaning to it
  - Meaning can only be assigned in context
- Context
  - Integer between 50 and 100
  - Represents temperature in this room in degrees F.
- If both sides understand the context
  - Only need representation of integer number
- If not
  - Common understanding may be English
  - Include description along with the temperature value

Information Representation

- Algorithm
  - Sequence of steps
    - Have common understanding of elemental steps
      - Depend on the way they are expressed
        - Machine instructions
        - Higher level language
        - Pseudocode
        - …

Multi-step Processing



Explicit and Implicit Information

- Explicit
  - Conveyed explicitly through messages etc.
- Implicit
  - Derived from explicit and the current knowledge of its relationships - perceived reality- models
  - Requires processing
    - Spending Resources: Time and Energy
  - Can be different for different agents !!

Meta-Information

- Ontology
- Levels of Meta Information?

What can we do with information

Using Information requires ACTION

- Create/capture
- Store
- Move/Retrieve
- Use
  - To derive implicit information – making it explicit
  - To determine some other action to be taken (Choice)
  - To activate a physical operation (output)

Storage of information

- In order to store any information which is explicit we need a representation for it
- In order to use it as information we need to retrieve it from storage
- A representation of information suitable for storage may not retain many interrelationships.
  - On retrieving
    - some may be recalculated
    - some may be lost forever
    - In particular – information relating to time will be lost unless time stamping is done
- Storing/Retrieving of Information are actions

Note that any and all actions generate lot more information than can be captured

Movement of information

- Only explicit (represented) information can be moved from one location to the other
- Information to be moved must be in a representation which is understood
  - and can be interpreted by the sender and the receiver.
- The understanding can come from explicitly represented agreements (which in turn require conventions - Protocols)
- It must be storable
- Requires an action

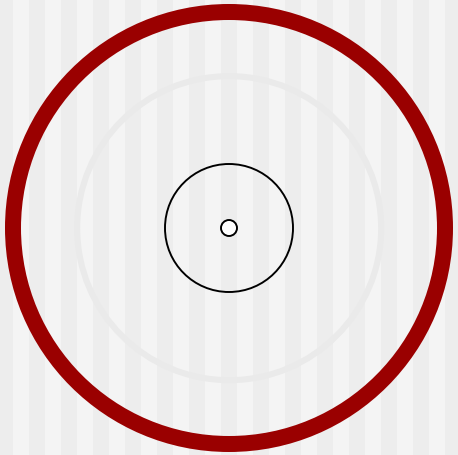
Information movement infrastructure

- Network
  - Provides the ability to move info from location x to y
  - Who initiates the move
    - When
    - Why
- How does y know that x has some information it needs?
- How does x know that y needs that information?

- Knowledge about where what information is?
  - Search Engines !!
    - Have to know where the search engine is and how to access it.

Implications of Information Movement

- Moving information from location x to location y takes time t_{xy}
- At y we can only get information from x which is at least t_{xy} old



Information Uncertainty Principle-1

- The perceived reality at any location CAN NOT be the same as the actual reality at any remote location of the global reality
  - Due to the transmission and processing delays
- It is not sufficient to receive the information
  - It must be interpreted and processed to integrate it with the current perceived reality
- Perceived reality at a location may be consistent with global/remote reality but can not be the same
- We can never have a complete model of another entity:
  - models abstract knowledge

Information Uncertainty Principle - 2

- Due to finite precision of measurement and representations we can never have complete and precise knowledge of any quantifiable information
- We deal with this uncertainty all the time !!!

Value of Information

- Implicit understanding of the value
- Is entity/agent specific
- Use in selecting – deciding among options for processing and taking action
- Value of information changes with time
  - Different for each agent
  - Depends on his perceived reality
  - Can not assign a fixed ordinal scale to the value

Value of Information

- Value may be captured by uncertainty models
- Example – queue length at a router
  - The knowledge of the queue length at time t may be precise
  - The knowledge at a later time given the value at t will have a variance which will increase with time
  - When we want to know the value of queue length from some other location, the information movement delay increases the variance

Information Fusion

Given Multiple observations –

- How to integrate them into one "view"
- One view may contain multiple options / likely scenarios

Capture of Information

- Two mechanisms
  - Observation –
    - Through direct or indirect observation/ monitoring/measurement
  - Processing of info – Make implicit information explicit
    - To enumerate interrelationships
    - To make deductions
    - To make inductions
    - Using models
- Example: Mathematics
  - A set of interrelationships with a description of when they apply
  - A framework for deductions and inductions to add to the information base
  - Analytical Results => defined interrelationships and descriptions of applicability

Action

- Physical Action
  - Results in physical manipulation
- Non- Physical
  - Thinking
    - Exploring inter-relationships
  - Processing within a computer

• All Actions take time and consume energy

• Begins with an information trigger!

• Usually done with respect to an event.

Action

- Requires Processing
- Starts under the control of "Trigger"
- Needs
  - Processor
    - Possibly other resources
    - For some time
  - At a location
  - Information as input
- Outcome
  - Additional Information
    - Explicit from Implicit
  - Trigger(s)
  - Storage
  - Movement
  - Physical results
    - Commands to actuators

Three Levels

- Information
- Represented Information
- Physical

Types of Actions

- Make implicit information explicit
- Carry out interpretation/storage/movement of information
- Carry out a physical action by issuing a command to a physical processor
- Transform some information into some trigger which is used to control some later action

Trigger

- Required for carrying out an action at a particular time/under some conditions
- Defines
  - What action, where, using what resources, at what time or under what conditions (priority, precedence etc.)
- Based on information/location/time/value
- Requires processing to convert information into a Trigger
- When relationships are fixed – hardwired design – Design time Trigger
- When relationships are dynamic trigger has to reflect it

Large Complex System

- A collection of N entities capable of carrying out certain operations
- Has a mission
- Physical resources which can carry out the actions
  - At various locations
- Mechanism for moving information (communication)

- Design Carried out at Information Level

Coordination: A Distributed System

- Information-centric view
- Many interacting autonomous agents
  - Who needs what information at what time
    - Why
    - How will he use it
  - Who has that information at what time
  - How to get the right information at the right place at the right time
  - Most algorithms – mechanisms for such movement of information with respect to elemental processing capabilities assumed

Role of Time

- Do we need a global/universal clock?
- What type of time is appropriate for Information Dynamics?
  - Absolute Time with a Counter (though it has a value relative to a starting point)
  - Relative Time through Causality

Consistency

- How can coordination take place without consistency of models each entity has from one another?
- Models between communicating entities must be consistent and accurate enough
- Who has the responsibility to fix broken models?
- Do models follow a set of rules?
  - Logically, relationally, or operationally.

Awareness

- In order for entity A to be aware of entity B, entity A must have a model of entity B.
- Entity B need not have a model of entity A.
- Being aware does not mean having complete knowledge of another.

Levels of Abstraction

- Any massively complex system has to be viewed at an appropriate level of complexity
  - Information with right degree of detail
  - Only relationships of interest and their connections of interest are retained

Planning

- Requires knowledge about future
  - Using Models
  - Estimates
    - Accuracy
    - Confidence
- Knowledge of Dynamics
  - Expected changes over time

Example – Mutual Exclusion Problem

- N Agents - Cooperative
- Any agent can enter its CS if nobody else is in its CS
- Check if anybody is in its CS
  - If not – enter
  - If yes – wait and try again
- Each action takes time
  - State of agents can change in that time

Entry

CS

Exit

Non – CS

LOOP

Mutual Exclusion Problem

- How to know the state of all other agents
  - Shared memory model
  - Distributed –
    - through messages
- Shared Memory Model
  - Set up a mechanism for sharing of state information
    - Semaphore
  - Delay
    - Atomic action
  - Define checking mechanism
- Distributed
  - Messages
- Algorithms vary in terms of the implications of messages and their meaning
- Simplest – Ask everybody for permission and enter when received from everybody
- How to process a permission request?

Example - Security

- Key – part of "perceived reality"
- How does B know which key to use?
- Public Key encryption

Example – Link State Routing

- Each node measures delays
- Periodically send the measured delay to every other node
- Determine route as the minimum delay path from source to destination

- Need delay when packet gets there not what it was
- Estimate of future delay rapidly moves towards the steady state values
- IF Steady State values are known
  - Reduce communication
  - Improve routing

- Demonstrated through implementation/simulation

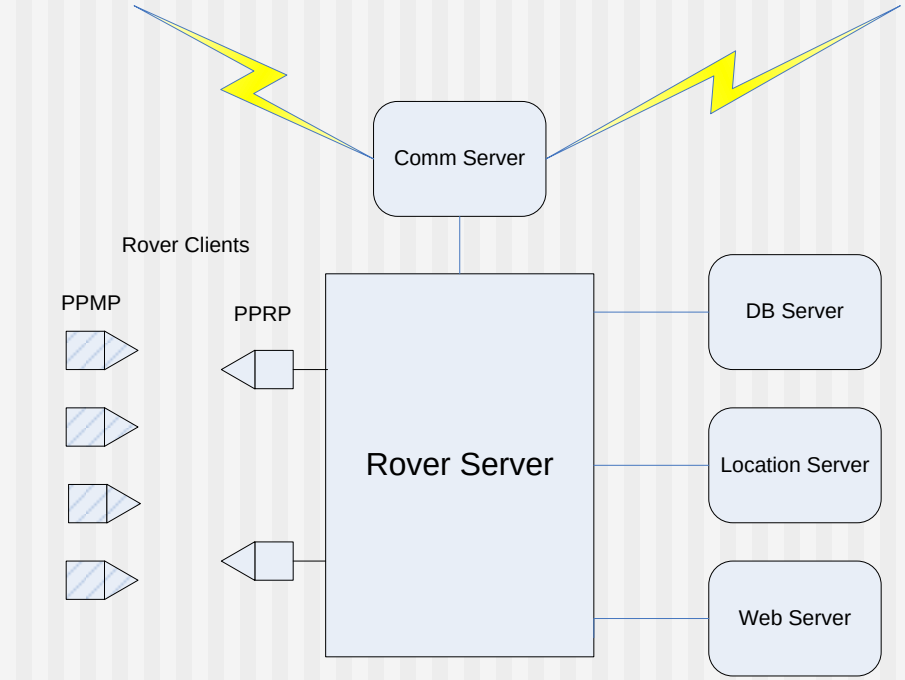
Information-centric Design

- Having right information at the right place at the right time
- Explicitly take into account the time dependent aspect of information
- Explicitly take into account the value of information
- Explicitly take into account implicit information
- Organize/design system based on the dynamics of information requirements

Rover Technology

- Context-aware computing platform
  - Location
  - Time
- Self-describing Information Representations
- Services/actions depend on context

Rover Technology



PPMP – PinPoint Mobile Point

PPRP – PinPoint Reference Point

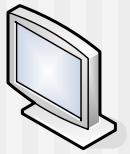
Rover Technology

- Designed to address issues in
  - Enterprise Applications
  - Command and Control Applications
  - Pervasive Computing
  - Sensor Networks
  - …

Rover Network Diagram

UMD Wireless Network
AV Williams Building, 3rd and 4th Floors
Unit 1
Unit 2

Units inform their position, performs tagging operations, and utilizes other services.



Watcher 1

MINDLab Network
8400 Baltimore Avenue
Watcher 1

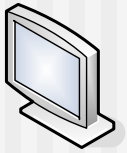
Listens for position activity, performs tagging operations, and utilizes other services.

Server

UMD/CS Unsupported Public Network
AV Williams Building, Room 4160

Mitigates Rover Services Between Rover Clients Including:

User Position Notification
Map Tagging
Text Chat
Internet Services



Watcher 2

UMD/CS Unsupported Private Network
AV Williams Building, Room 4160
Watcher 2

Listens for position activity, performs tagging operations, and utilizes other services.

The Internet

Rover Server accesses internet services as a proxy for Rover Clients, with Services including (with support for caching):

Yahoo! News and Web Searches via REST
Yahoo! Weather RSS Feeds

Uses of Information Dynamics

- Framework for
  - Approaching system designs
  - System Analysis
    - Given a design determine
      - All Information Dynamics – Explicit and Implicit
      - Decision Structure
      - Actions
  - System Synthesis
    - Outcome required
      - Processing/Action needed
      - Information needed

Questions???